

SLMS™ Athermal Technology for High Quality Wavefront Control of HEL Tactical Airborne and Relay Mirror Beam Control Applications

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Capt. Ryan Conk Air Force Research Laboratory Directed Energy Directorate



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**Mirror Technology Days
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Outline

- Program Description
- Phase II Project Scope
- Latest Results

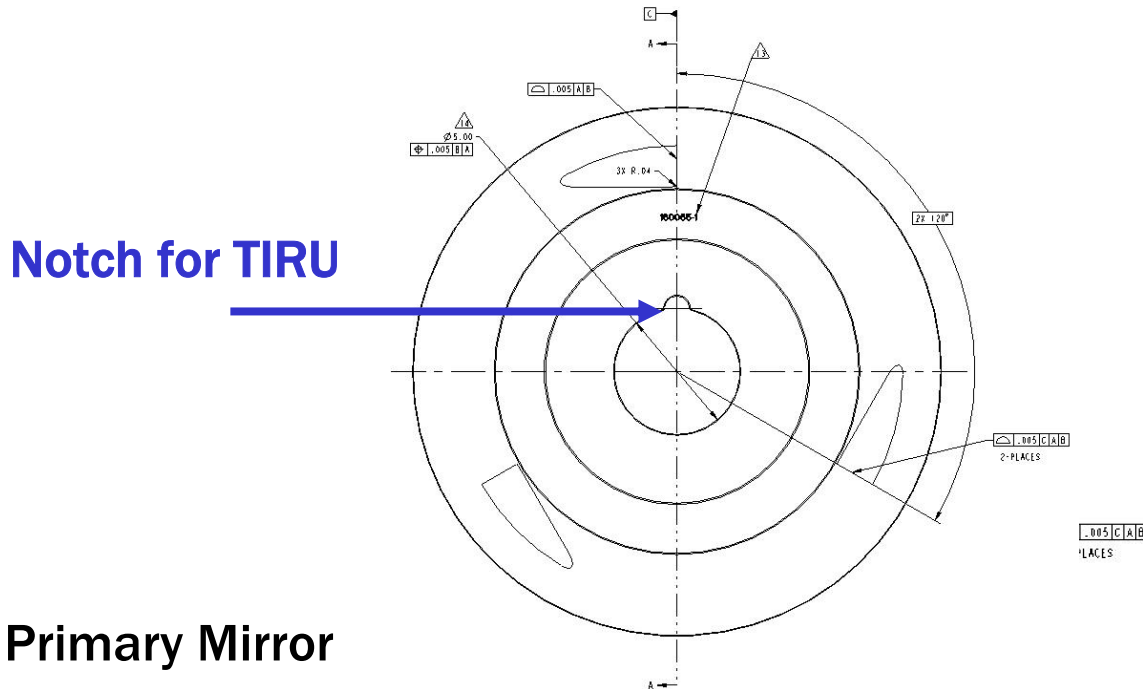
Program Description

- Operational environment for Tactical Airborne missions typically -20 °C
- Operation environment for Relay Mirror Systems typically -50 °C
- Desirable attributes for mirrors/beam directors of these systems are:
 - ⇒ High Quality Wavefront Control
 - Very Low Absorption (VLA) Coatings for Low Thermal Distortion
 - Superior Cryogenic Performance Without Print-Through
 - Super Polishing with Low Cost
 - High Structural Efficiency (Self Damping)
 - High First Fundamental Frequency
 - ⇒ Low Weight
- Demonstrate prototype mirrors for the beam control system

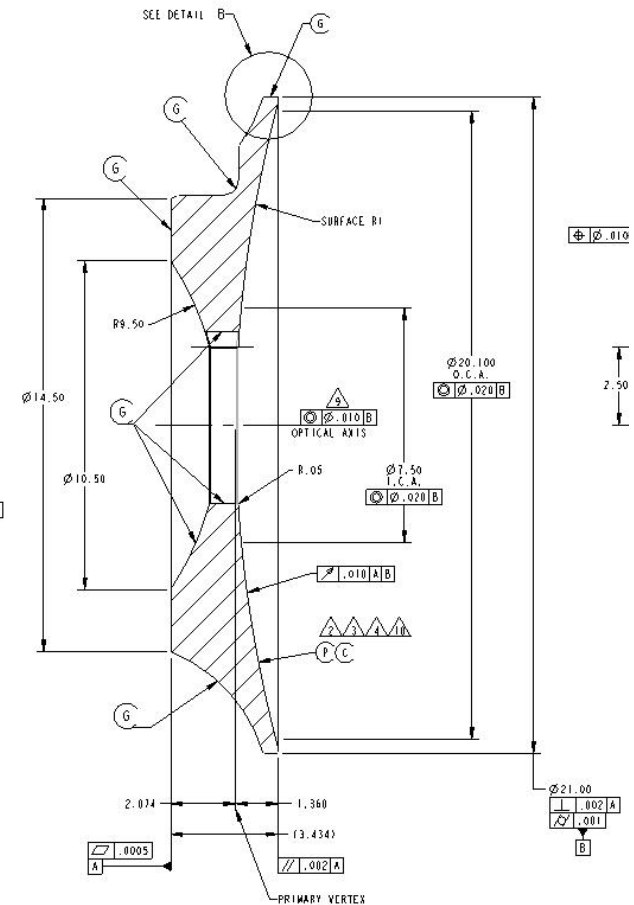
Phase II Project

- **Design and Fabricate SLMS™ Beam Director Primary Mirror**
 - ⇒ 50 cm Clear Aperture
 - ⇒ $F/\# = 1.00$
 - ⇒ $K = -1$ (Parabola)
 - ⇒ Customer specified NIR laser coating
- **Design and Fabricate Athermal Mirror Mount for Simulating and Testing in Relevant Operational Environment (proprietary)**

Physical Details of PM



- **Primary Mirror**
 - ⇒ **21-inch diameter solid Zerodur Parabola ($K = -1$)**
 - ⇒ **Radius of curvature = 39.287 in**
 - ⇒ **Notched for TIRU beam insertion**
 - ⇒ **Double arch design**



Classical Sculpted Design > 15 years old
Lowest Deflection:Weight Ratio = 0.04
Very Fast, f/# = 1.0

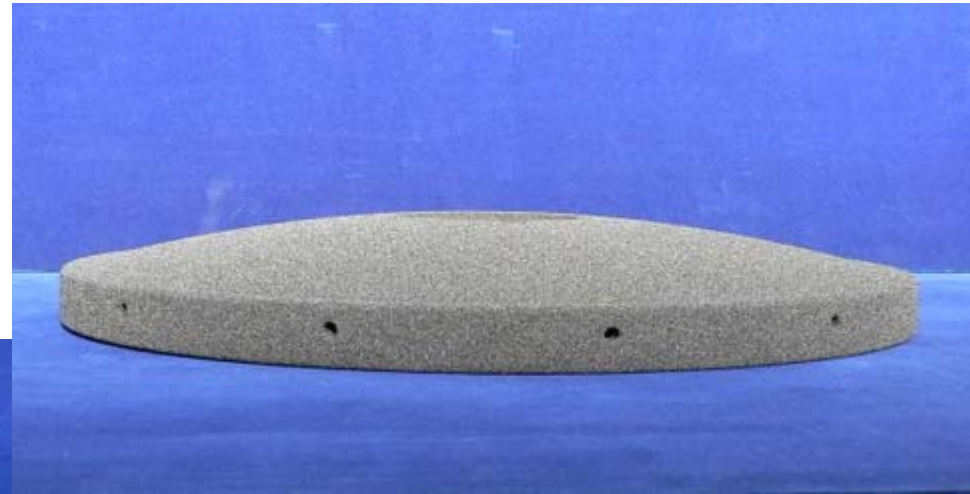
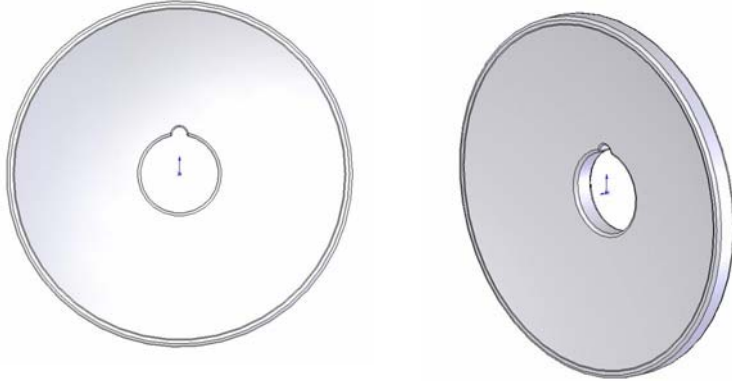
Basic Primary Mirror Specs

- Clear Aperture Diameter: 50 cm
- f/#: 1.0
- **As-Polished** Wavefront Error (residual surface error w/ tilt & focus removed): 0.0169 waves rms @ 1.315 μm (0.035 waves rms HeNe)
- Weight: 46 lbs (**Areal Density of 93.57 kg/m²**)
- Coating Spec:
 - ⇒ Reflectivity:
 - 1.315 -1.319 μm : 0.9992
 - 1.06 - 1.08 μm : 0.9900
 - 0.633 μm : 0.9000
 - 0.91 μm : 0.9900
 - ⇒ Absorption: <200 ppm
 - ⇒ Scatter: <300 ppm
 - ⇒ Damage Threshold: >20 kW/cm²
 - ⇒ VLA Coating Provides Relatively No Thermal Distortion

Figure Requirement Well Within Capability for SLMS™
Classical Zerodur Double Arch Design is Very Heavy
Coating Performance is Very Reasonable

SLMS™ Primary Mirror

- Schafer Mirror Requirements Captured in an ISO9001:2000 Drawing



Mass of 3.05 kg (6.7 lbs)

C/SiC Mount/Manifold

- C/SiC Provides CTE Matched High Stiffness Mount with Integral Manifold for Environmental Simulations.



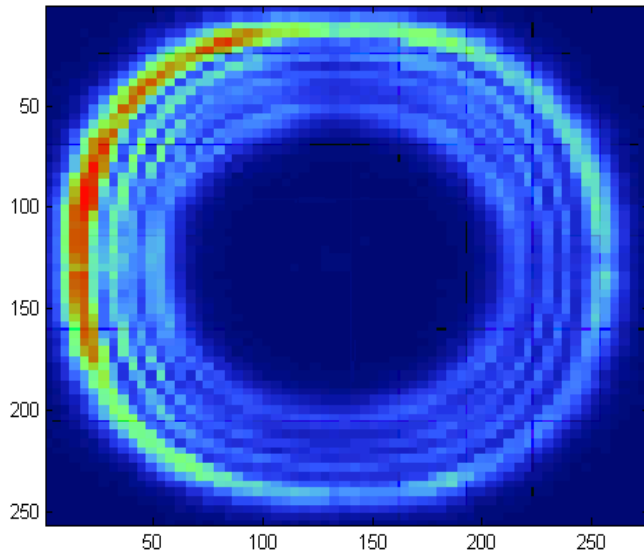
Mass of 9.5 kg (20.9 lbs)



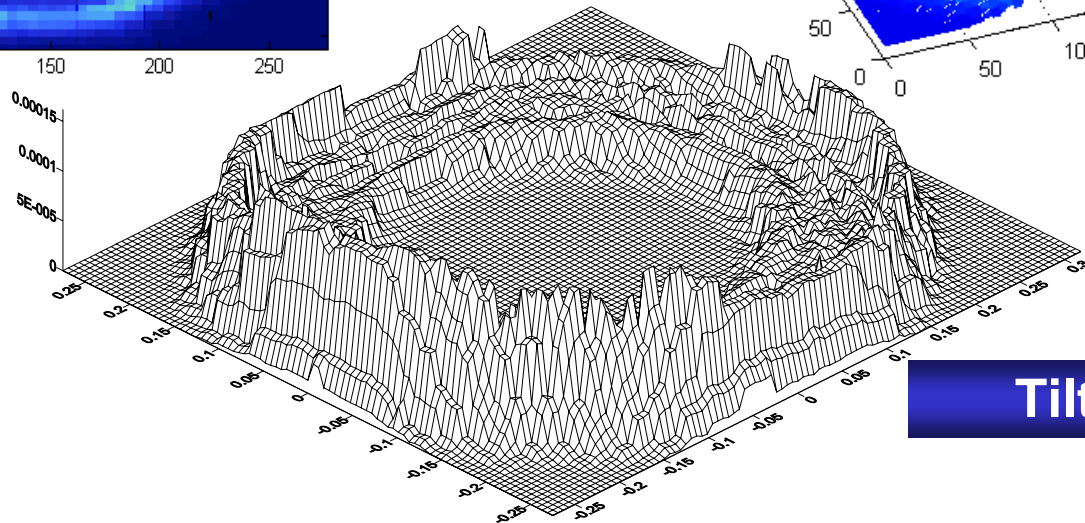
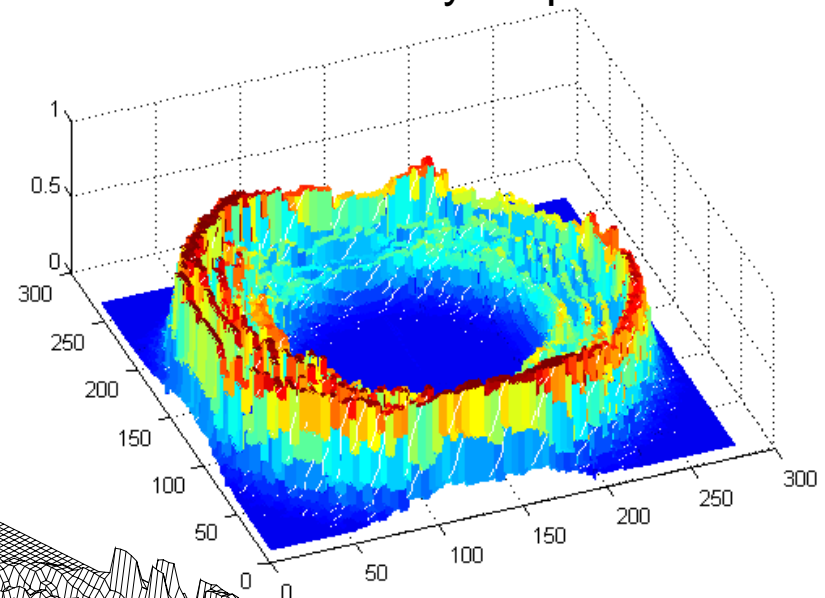
Intensity Distribution

Map as shown in presentation:

“Primary Mirror Specifications for AFRL”

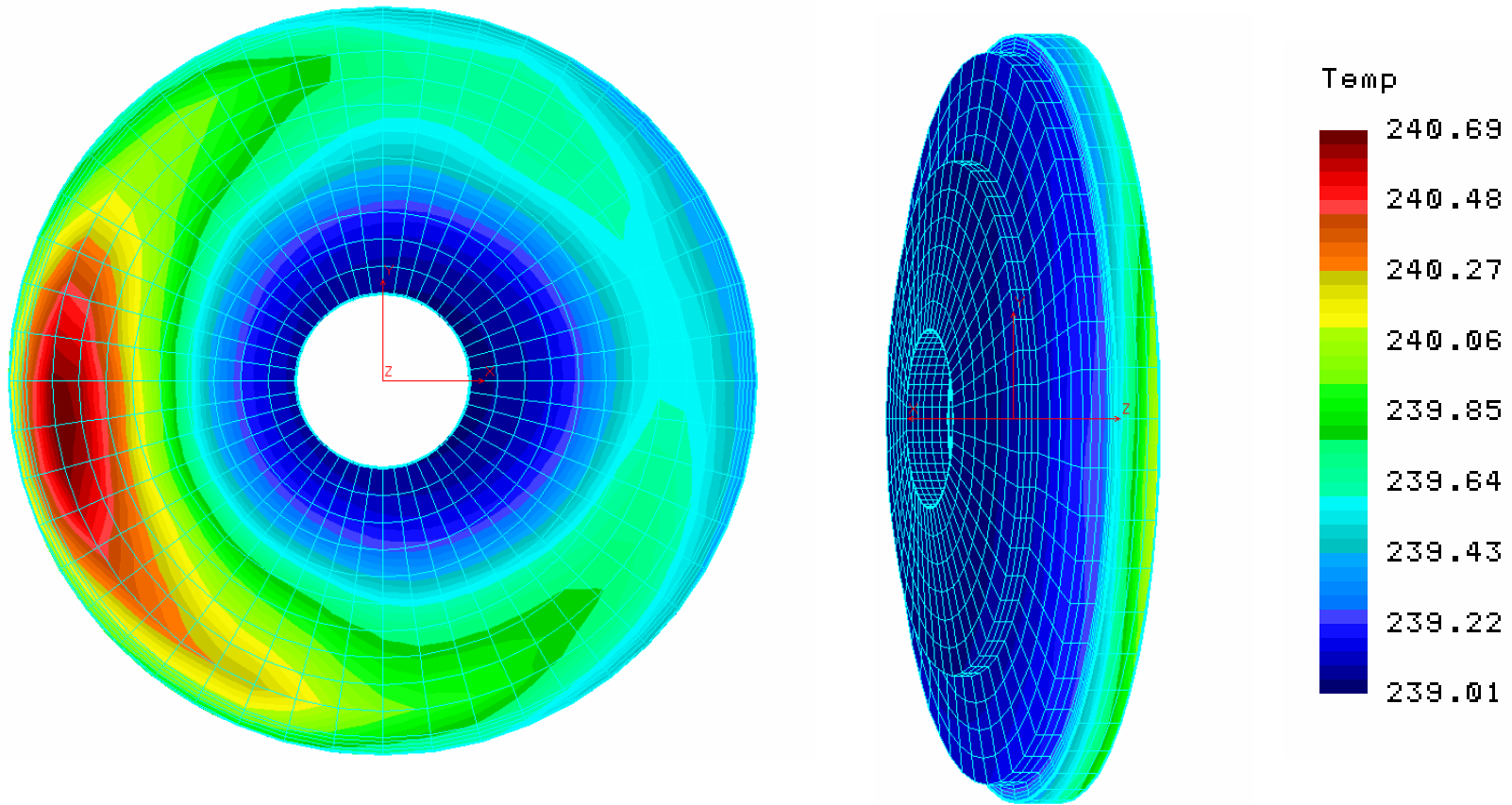


Schafer Processed the 2-D Intensity Plot and Generated a Normalized 3-D Intensity Map



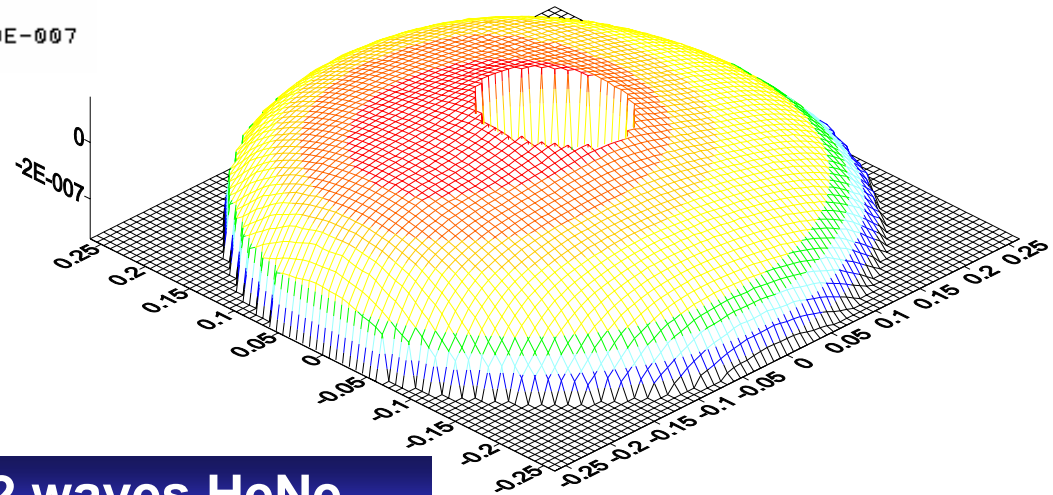
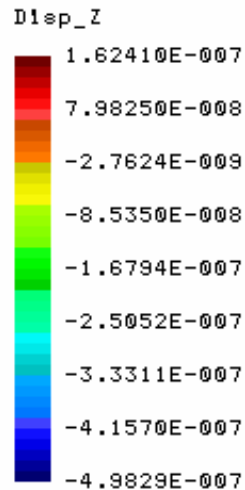
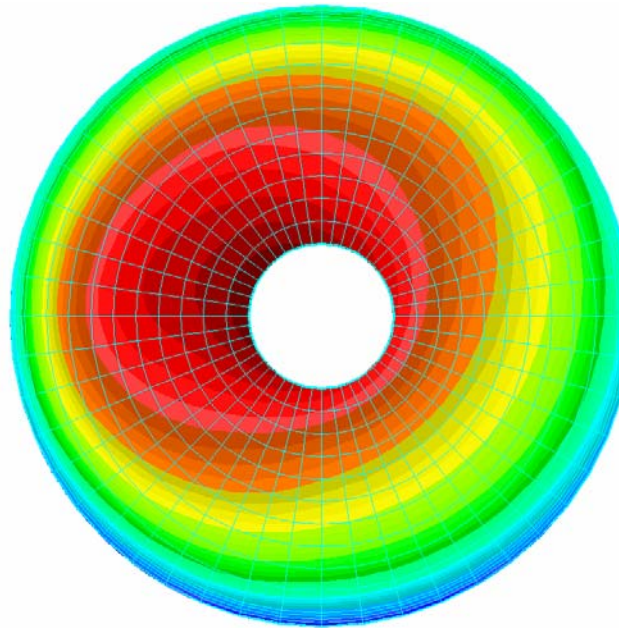
Tilt Expected

Temperature (K) at 50 sec



Peak Temperature Rise ~1.7 K
Mount Acts As A Heat Sink

Surface Distortion (meters)



P-V Surface Distortion is 0.82 waves HeNe
RMS (nothing removed) is 0.17 waves HeNe

Zernike Coefficients

| Description | 50 sec |
|-----------------|-----------|
| PISTON | -3.73E-02 |
| TILT X | -9.80E-02 |
| TILT Y | 1.08E-01 |
| FOCUS | -2.60E-01 |
| ASTIGMATISM X | 2.99E-02 |
| ASTIGMATISM Y | 1.24E-02 |
| TREFOIL X | -1.10E-02 |
| COMA X | 2.81E-02 |
| COMA Y | 9.20E-03 |
| TREFOIL Y | -1.28E-03 |
| TETRAFOIL X | 1.11E-02 |
| 2 ASTIGMATISM X | -4.86E-03 |
| SPHERICAL | -4.42E-02 |
| 2 ASTIGMATISM Y | -1.13E-03 |
| TETRAFOIL Y | -1.13E-03 |
| PENTAFOIL X | -2.72E-03 |
| 2 TREFOIL X | 3.04E-03 |
| 2 COMA X | 8.56E-03 |
| 2 COMA Y | 3.55E-03 |
| 2 TREFOIL Y | 2.07E-03 |
| PENTAFOIL Y | -3.19E-03 |
| HEXAFOIL X | 1.58E-03 |
| 2 TETRAFOIL X | 1.06E-02 |
| 2 ASTIGMATISM X | -3.38E-03 |
| 2 SPHERICAL | -2.98E-02 |

****In He-Ne waves**

| Description | 50 sec |
|---------------------------------|-----------|
| INTEGRATED FUNCTION VALUE | -4.20E-08 |
| PEAK ERROR IN HeNe WAVES | 2.37E-01 |
| VALLEY ERROR IN HeNe WAVES | -5.78E-01 |
| P-V SURFACE ERROR IN HeNe WAVES | 8.15E-01 |
| AVG SURFACE ERROR IN HeNe WAVES | -2.17E-02 |
| NUMBER OF POINTS | 3853 |
| SUM | -8.36E+01 |
| RMS SURFACE ERROR IN HeNe WAVES | 1.74E-01 |
| SUM OF SQUARES | 7.36E-04 |

NOTE THAT AN ANNULAR ZERNIKE PROCESSOR WAS
NOT USED FOR THIS DECOMPOSITION,

**Tilt and Focus
Dominate As
Expected**

Benefits to Government Programs

- **27.6 lbs vs 46 lbs for Zerodur,**
 - ⇒ Requirements Can be Relaxed for Gimbal and Motors
 - ⇒ Lighter Mirror Mounts, Structure and Counterweights Can Be Employed
- **Primary Mirror First Fundamental Frequency of ~760 Hz**
 - ⇒ Increased Stiffness and High Damping Allows Reduced Ringdown Time and Jitter During Slew, Improves Beam Director Line of Sight
- **Small f/# Optics Required for Numerous Optical Systems**
 - ⇒ Faster Mirrors Result in Lower Inertial Loads on Gimbals (Shorter Telescope)
- **SLMS™ Shown to Have Better Dimensional Stability Than Zerodur**
 - ⇒ Foam Provides A Well Supported Facesheet (No Quilting)
 - ⇒ High Conductivity Skin, Does Not Irradiance Map, Proven in Laser Testing
 - ⇒ High Stiffness, High Thermal Diffusivity, Does Not Print-Through at Cryo (Proven at NASA MSFC and GSFC)
- **SLMS™ Demonstrated With VLA Coating Technology**

SLMS™ Are A Breakthrough Technology For Tactical Airborne Beam Control Applications

SLMS™ in Conjunction with VLA coating technology offers Dramatic Improvement for Tactical Airborne and Relay Mirror Systems

High Quality Wavefront Control

Low Polishing Cost

Very Low Absorption (VLA) Coatings for Low Thermal Distortion

Superior Cryogenic Performance for No Print-Through

High Structural Efficiency

High First Frequency